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EFFECTS OF SALT AND SODIUM TRIPOLYPHOSPHATE ON TEXTURE, ORGANIC VOLATILES AND SENSORY CHARACTERISTICS OF IRRADIATED AND NONIRRADIATED PORK ROLLS

Irradiated Food Products Group
Radiation Preservation of Food Division

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Radappertized pork rolls were prepared using fresh pork hams with sodium chloride (0.75%) and sodium tripolyphosphate (0.3% or 0.5%) additions. The irradiated and nonirradiated samples were tested by technological panels for the sensory characteristics and consumer panels for preference. Texture measurements were made with an Allo-Kramer Shear Press. Total organic volatiles were determined using a steam distillation method. The addition of 0.75% NaCl and 0.3% or 0.5% TPP resulted in a significant improvement in the sensory characteristics and preference ratings of the irradiated pork rolls. Textural

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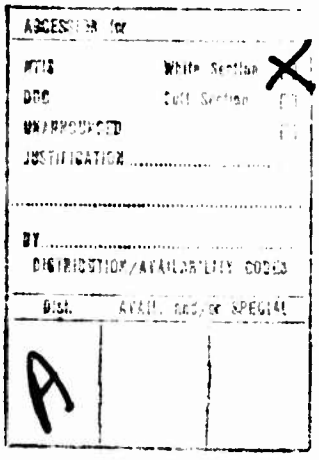
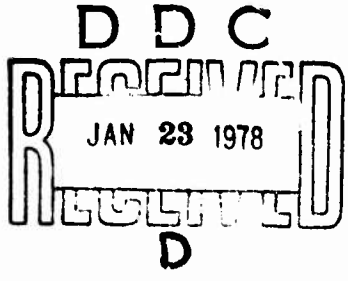
measurements from the shear press showed significant improvements with the addition of NaCl and further improvements with TPP additions. No organic volatiles were found that could be attributed to the addition of the NaCl or TPP.

SUMMARY

Sodium chloride (NaCl) and sodium tripolyphosphate (TPP) additions to irradiated pork rolls resulted in improvements in the preference ratings when evaluated by consumer panels. NaCl alone was not sufficient. NaCl (0.75%) and TPP (0.3% or 0.5%) additions had no effect on color ratings, but resulted in improvements in the flavor quality. Textural ratings from technological panels were significantly improved by the addition of NaCl and further improved by TPP addition. Shear press readings showed significant changes with the additions of NaCl and 0.3 and 0.5% TPP, confirming data received from the technological panels. No volatile compounds were produced that could be attributed to the addition of NaCl and TPP. No significant differences were found in ratings for the sensory characteristics and preference, total organic volatiles, or shear press readings between 0.3% and 0.5% TPP addition. Therefore, the optimal level of TPP addition to irradiated pork is 0.3% when used in combination with NaCl.





PREFACE

The investigations reported in this paper were conducted to determine the effects of sodium chloride and sodium tripolyphosphate on the sensory characteristics and organic volatiles in pork muscle. Total organic reducing volatiles were determined and textural measurements were taken using an Allo-Kramer shear press.

Results from these investigations have shown that acceptable irradiated pork can be produced using 0.75% sodium chloride and 0.3% tripolyphosphate to produce a cut-and-formed roll-type item.

These studies were undertaken as a research project by the Irradiated Food Products Group, Radiation Preservation of Food Division, Food Engineering Laboratory, under Project 1Y762724AH99.

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EFFECTS OF SALT AND SODIUM TRIPOLYPHOSPHATE ON TEXTURE, ORGANIC VOLATILES AND SENSORY CHARACTERISTICS OF IRRADIATED AND NONIRRADIATED PORK ROLLS

INTRODUCTION

The changes in the physical and chemical properties of meat and poultry resulting from the addition of salt, sodium chloride, and food-grade phosphates have been well documented in the research literature. Changes in the pH of meats caused by phosphate addition and its effects on water retention were reported by Grau[1] et al. (1953), Hamm[2] (1960, and Swift[3] and Ellis (1956). Mahon[4] (1961) found that NaCl concentration, not pH adjustment, was the primary factor in obtaining maximum water retention in meat. Mahon also reported a synergistic effect on water retention by the addition of NaCl and phosphates.

Hellendoorn[5] (1962) found that pyrophosphate and tripolyphosphate yielded great effect on water retention in pork when heated, with pyrophosphate being superior. Sherman[6] (1961) working with fresh pork with phosphate additions in a range not exceeding 2% and heated in a range of 25° to 100°C showed that 50°C yielded the maximum water retention values; higher temperature decreased the water retention.

However. at 50°C proteolytic enzymes are not inactivated in pork (Chiambalero[7] at al. 1959) and, therefore, maximum retention of water in irradiated pork items cannot be realized due to tha higher temperatures necessary for enzyme inactivation (71° - 75°C).

1. Grau, R., R. Hamm, and A. Bauman, 1953. Water-binding capacity on mammalian muscles. Tha influenca of pH valuas on tha watar binding capacity of ground beaf muscla. Biochem. Z. 325:1.

2. Hamm, R., 1960. Biochemistry of maat hydration. Ad. in Food Res. 10: 355.

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6. Sherman, P., 1961. The water-binding capacity of fresh pork. I. The influence of sodium chloride, pyrophosphate and polyphosphate on water absorption. Food Tech. 15: 59.

7. Chiambalero, C. J., D. A. Johnson, M.P. Drake, 1959. A time-temperature relationship for heat-enzyme inactivation of radiation sterilized beef and pork, J. Agr. Food Chem., 7: 783.

Shults and Wierbicki (1974) reported the effects of NaCl and food-grade phosphates in pork muscle. It was determined that pyrophosphate, and to a lesser extent, tripolyphosphate were more beneficial for reducing cooking losses in fresh pork muscle. This agrees with work on comminuted pork meat by Hellendoorn[5] (1962). It was also found that 0.3% addition of phosphate yielded maximum results for meat swelling properties and water holding capacity when used in combination with 1% NaCl.

Most of the previous work on the effects of NaCl and phosphates in pork has been associated with comminuted or cured pork. However, this is not the case with the development of a cold, ready-to-eat uncured pork item preserved by radappertization. For meat rolls, the binding mechanism of the added salt in combination with phosphates is most important. The addition of NaCl and phosphates results in a migration of a salt soluble protein to the surface of the meat, and on denaturation these salt soluble proteins form a binding matrix. This protein binding of meat chunks results in a product that can be molded into configuration to fit any desired container. Shaping of the meat into uniform dimensions allows the maximum utilization of the containers and is beneficial in reducing the variation of irradiation dose.

The objective of these tests was to demonstrate the necessity of salt (NaCl) and phosphate additions to pork prior to enzyme inactivation and packaging by showing the improvements in the flavor and texture characteristics and improved acceptance of the finished radappertized pork rolls. The effects of the addition of NaCl and phosphates were determined using organoleptic, chemical, and physical testing of the irradiated pork roll, with nonirradiated counterparts as controls.

Materials and Methods

The raw material for this study was fresh (3 to 7 days post slaughter) boneless pork hams, skin and external fat removed. The hams were cut into 50 to 500 gram chunks and mixed in a mechanical mixer with or without additives for five minutes. The additives used were sodium chloride (0.75% level) and food-grade sodium tripolyphosphate (0.3 and 0.5% levels). All samples included 3% crushed ice for temperature control and to facilitate mixing of the additives with the meat. After mixing, the product was stuffed into 102 mm diameter fibrous, regenerated cellulose casings. The meat rolls were held at 2 to 5°C overnight (15 to 18 hours) prior to enzyme inactivation in a cookhouse to an internal temperature of 70° to 75°C.

After enzyme inactivation, the rolls were chilled at 2 to 5°C, packaged into cans, sizes 404 x 700 and 404 x 202, under a pressure of 7kPa + 1 kPa. The sealed cans were frozen to -30°C to -40°C prior to irradiation.

3. Shults, G. W., and E. Wierbicki, 1974. Effects of condensed phosphates on the pH water-holding capacity and meat swelling properties of pork muscle. TR-74-22FL, U. S. Army Natick Laboratories.

Irradiation of the product was carried out in the cobalt-60 source at the US Army Radiation Laboratory, US Army Natick Research and Development Command, Natick, Massachusetts. All samples received a gamma-irradiation dose in the range of 5.1 to 6.1 Mrad. Temperature during irradiation was controlled at -30°C+10°C using liquid nitrogen. Dose rate was 3.79×10^4 rads per second. Samples were stored at 21°C for 0 to 30 days after irradiation. Nonirradiated controls were held frozen at -29°C until evaluation.

Meat Shrinkage

Meat shrinkage (reciprocal of water-holding capacity) was determined by the method of Wierbicki[9] et al. (1957) with modification by Shults[10] et al. (1973).

Sensory Evaluation

Samples were subjected to trained technological panels of 10 to 12 panelists, who evaluated them for the sensory characteristics of odor, flavor, color and texture. The sensory characteristics ratings were scored using an intensity scale of 1 (extremely poor) to 9 (excellent). In one experiment, the experimental samples were sensory tested for the following off-characteristics: discoloration, off-odor, off-flavor and texture.

Preference ratings were obtained using both the trained technological (N - 8 to 10 panels) and consumer type panels (N - 32 to 36). Indications of preference were made on a hedonic scale of 1 to 9 by preference, with 1 being "dislike extremely" and 9 meaning "like extremely" (Peryam and Pilgrim, 1957). A rating of 5, "neither like nor dislike", was considered the baseline for the acceptability of the product.

Texture determination (Shear Press)

Pork slice tenderness was measured using an Allo-Kramer Shear Press modified to function as a penetrometer by substituting the standard shear compression cell and shearing blades with an apparatus containing five 3.2 mm diameter drill rods, semi-blunt, having 1.5 mm diameter land and 6.7/25.4 mm taper. Readings are expressed in newtons (Hinnergardt and Tuomy, 1970).[12] The meat

9. Wierbicki, E., L. W. Kunkle and F. E. Deatherage, 1957. Changes in the water-holding capacity and cationic shifts during the heating and freezing and thawing of meat as revealed by a simple centrifugal method of shrinkage. Food Tech. 11: 69.

10. Shults, G. W. and E. Wierbicki, 1973. Effect of sodium chloride and condensed phosphates on water-holding capacity, pH and swelling of chicken muscle. J. Fd. Sci. 38: 991.

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12 Hinnergardt, L., and Tuomy, 1970. A pentrometer test to measure meat tenderness. J. Fd. Sci. 35: 312.

rolls were sliced into 12.7 mm slices, and three readings were taken per slice, 12 replicates for each variable. The higher the reading, the lower the tenderness of the pork slices.

Total Organic Reducing Volatiles

The total organic volatiles were determined using a steam distillation of organic volatiles into an alkaline permangenate solution, oxidation of the organic volatiles by the oxygen from the permanganate solution (first in alkaline and then in an acid medium made by addition of dilute sulfuric acid) and determination of the residual, unused permanganate by titration with standardized ammonium oxalate solution (0.1 N $(NH_4)_2C_2O_4$). A 50-9 sample of meat was added to 350 ml of distilled water and homogenized for 90 seconds. The homogenate was placed in a 200 ml flask with 5 ml picric acid and glass beads. Seventy ml (determined experimentally to collect all the volatiles) were distilled into a 500 ml erlenmeyer flask containing 50 ml of 0.05 N KMnO4 and 5 ml of 0.1 N NaOH. The receiver flask was refluxed for 10 minutes and 10 ml of dilute H_2SO_4 (1 to 3) added to the solution. The solution was refluxed for an additional 25 minutes. Following the reflux, 25 ml of standardized 0.1 N $(NH_4)_2C_2O_4H_2O$ were added, and the solution back titrated with standardized 0.05 N $KMnO_4$ solutions. This procedure is a quantative determination and the results are expressed in milliequivalents of oxygen consumed by the volatiles obtained from 100 grams of meat. Calculations are as follows:

$$\text{Milliequivalents O} = \frac{\text{ml } KMnO_4 \times \text{N } KMnO_4 \times 100}{\text{Sample Weight (g)}}$$

Statistical Analyses

Statistical analyses were performed on all data to determine significant differences between the samples in respect to the sensory characteristics. preference ratings, shear press, and volatile compound data. Significance was determinedat the five-percent level by using an analysis of variance and multiple range test, (Steel and Torrie, 1960).[13]

RESULTS AND DISCUSSION

Water-holding capacity (Meat Shrinkage)

The addition of sodium chloride in combination with small amounts of food-grade phosphates has been shown to be beneficial in reducing the meat shrinkage in beef and chicken meat (Shults[14] et al. (1972) and Shults[10] and Wierbicki (1973). Table 1 reports the results of the addition of 0 to 10 sodium tripolyphosphate (TPP) on the water-holding capacity of semimembranosus muscle of fresh pork ham. The TPP was used with and without NaCl addition.

13. Steel, R. G. and J. H. Torrie (1960) Principles and Procedures of Statistics 1st Ed., McGraw Hill.

14. Shults, G. W., D.R. Russell and E. Wierbicki, 1972. Effects of condensed phosphates on pH, swelling, and water-holding capacity of beef. J. Fd. Sci. 37:860.

The addition of 0.1% or 0.2% TPP did not significantly reduce meat shrinkage. Significant differences were not found in meat shrinkage values when 0.3, 0.4, or 0.5% TPP were added in comparison with the 0.1 and 0.2% additions. This was true for samples with and without NaCl additions. The additions of NaCl in combination with TPP resulted in highest overall reduction in meat shrinkage values.

The actual cookhouse yield data for pork rolls are tabulated in Table 2. The samples with 0.3 or 0.5% TPP had significantly less cooking loss than the samples without the additives. Differences in the yield data were not noted for samples with 0.3 or 0.5% TPP. The cookhouse data confirms experimental data obtained studying the water-holding capacity of pork shown in Table 1. Salt level in the pork rolls was 0.75%. This NaCl level was selected in order to keep the total amount of the additives low and to have a finished product without a salty taste.

Effect of Phosphate Level

The affects on the organoleptic quality and preference ratings of non-irradiated pork rolls prepared with 0.75% NaCl and three levels of TPP (0.0, 0.3, and 0.5%) are shown in Table 3. Storage conditions were 21°C for 0 and 30 days. At 0 time storage, significant differences were found for texture ratings between the sample with no additives and samples with 0.75% NaCl and those with 0.75% NaCl and 0.3% TPP.

The sample with 0.75% NaCl and 0.5% TPP rated higher for the sensory characteristics than the sample with no additives, but the difference was not significant. Preference ratings were not significant for any of the samples.

At 30 days storage, the sample with 0.75% NaCl and 0.5% TPP was rated significantly higher for flavor than the sample with no additives. Differences in color ratings were noted between 0 and 30 days storage, but these differences can not be attributed to any additive effect.

The results from technological examination of the irradiated pork rolls at 0 and 30 days storage are shown in Table 4. The sample with no additives was rated lower for flavor and texture at 0 days storage, but this did not hold true at 30 days storage. All samples were rated in the acceptable range for both sensory characteristics and preferences.

Table 5 shows the results of technological panel examinations of the irradiated samples compared to a frozen control (0 Mrad) containing 0.75% NaCl and 0.3% TPP. The ratings for the sensory characteristics of the irradiated sample with 0.75% NaCl and 0.3% TPP were found significantly different at 0 and 30 days storage. This sample was rated unacceptable (ratings below 5.0 are considered unacceptable) for color, odor, and flavor characteristics at 0 time storage. However, at 30 days storage, the sample scored very acceptable for the sensory characteristics and preference and was significantly better than the samples with no additives. The differences in this particular sample were attributed to container failure of the 0-time storage sample which allowed oxidation of the fat components. This resulted in discoloration and rancidity development.

At 30 days storage the sample with no additives was rated unacceptable for the textural and odor characteristics. Additionally, the samples with 0.3 and 0.5% TPP were rated more acceptable than the samples without TPP added. The color and flavor ratings for the irradiated samples were not significantly different at 0 or 30 days storage. This indicates that NaCl and TPP have little or no effects on these characteristics at the addition levels used.

Large member consumer-type panels were used to determine consumer acceptance of the pork rolls. Table 6 shows the results for the consumer evaluations of the same products tested by technological panels as shown in Tables 3, 4 and 5. In the test of the non-irradiated samples, the sample with no additives was rated significantly lower than samples with the additives. Differences were not found in ratings of the three samples containing additives. Consumer ratings for the four irradiated samples show that the sample with no additives was unacceptable and significantly lower from the three samples with additives. The sample with 0.75% NaCl and 0.5% TPP was rated significantly better than the sample with 0.75% NaCl without TPP. Evaluations in the test comparing the four irradiated samples with a nonirradiated control sample. Significant differences were not found between 0.3 and 0.5% TPP additions. The overall results emphasize the necessity for adding NaCl and TPP in the rolls to produce acceptable irradiated pork. The addition of NaCl alone was not sufficient to produce a highly acceptable irradiated pork.

Effect of Sodium Chloride Level

The effects of NaCl addition in a range of 0 to 1.5% TPP were studied. Table 7 shows the results from the technological panels at 30 days storage at 21°C. Preference ratings for the samples with no additives and 0.5% NaCl were significantly different from the control. The sample with 1.5% NaCl was rated significantly higher than the sample with no additives. No significant differences were found in the preference scores of the three samples with NaCl added.

Consumer evaluations on nonirradiated pork rolls with various concentrations of NaCl and 0.5% are shown in Table 8. The overall evaluation of the data obtained at the three storage times shows that the sample with no additives scored significantly lower than samples with NaCl and TPP added. Differences between the samples with the additives were small and not significant at the 5% level. The data in Tables 7 and 8 reveal that up to 1.5% NaCl can be added without any effects on the sensory characteristics or preference rating. However, a concentration of 0.75% NaCl was selected for use in pork roll to obtain an end product with no salty taste and improved overall quality as compared with pork rolls without the additives. Also, this level of addition was selected in an attempt to keep additive levels at a minimum. Results in Table 1 had shown the 0.3% TPP was adequate for the beneficial effects on the water-holding capacity of pork.

The effects of the addition of 0.75% NaCl with and without 0.3% TPP were studied using pork rolls stored at 21°C and tested by technological panels at 1 and 3 months (Table 9). At both the 1 and 3 month evaluations, the samples with added TPP 0.3% and NaCl 0.75% were rated higher for flavor,

odor, and texture than samples without the TPP. This held true for both storage times and also the nonirradiated control. These evaluations clearly show that the addition of a small amount (0.3%) of phosphate is beneficial for improvements in the flavor and textural characteristics of pork roll.

Total Organic Voletile Concentration

The total organic volatiles were determined on the irradiated and non-irradiated samples at 0 and 30 days storage. The data shown in Table 10 represents the organic reducing volatiles expressed as milliequivalents of oxygen per 100 grams of meat. The data indicated that no additional total organic voletiles were detected that could be attributed to the addition of TPP or NaCl to the pork. No significant differences were detected between 0 and 30 days storage of the pork rolls. However, the irradiated samples did show a slight increase in the total organic voletiles, but this increase was not significant ($P < .05$).

Texture Determination (Shear Press)

Sheer press studies were performed on the irradiated and nonirradiated frozen control samples after 30 days storage (Table 11). The data show that the addition of NaCl and TPP significantly affected the sheer press values for both irradiated and nonirradiated samples. No differences were found in samples with 0.3 and 0.5% TPP addition, but these samples were significantly different from the samples with no additives and 0.75% NaCl alone. Also, the addition of 0.75% NaCl alone significantly effected the texture of the irradiated pork roll. Significant differences were found between irradiated and nonirradiated samples in all cases, except the sample which contained no additives. The conclusion drawn from this data is that NaCl addition results in improvements of the texture, and additional improvements can be obtained by the addition of TPP. These data confirm the data derived from technological panel observations.

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14. Shults, G.W., D.R. Russell and E. Wierbicki, 1972. Effects of condensed phosphates on pH, swelling, and water-holding capacity of beef. J. Fd. Sci. 37:860.

TABLE 1 Effect of sodium tripolyphosphate and sodium chloride additions on the pH and water holding capacity of pork muscle - semimembranosus

Sample			Replications					
% NaCl	% TPP	pH	1	2	3	Average	% Shrink	Multiple * Range Test
0	0.0	5.4	7.5	8.0	8.0	7.8	39.1	
1	0.0	5.4	7.2	7.8	7.2	7.4	37.0	
1	0.1	5.5	7.7	7.6	7.4	7.6	37.8	
1	0.2	5.6	6.7	6.8	6.8	6.8	33.8	
1	0.3	5.7	4.7	5.4	5.7	5.3	26.3	
1	0.4	5.8	4.8	5.1	5.6	5.2	25.8	
1	0.5	5.8	5.1	5.1	5.0	5.1	25.3	
1	1.0	6.0	3.0	3.4	3.7	3.4	16.8	
0	0.1	5.5	7.6	7.4	7.6	7.5	37.6	
0	0.2	5.6	7.2	7.8	7.6	7.5	37.6	
0	0.3	5.7	6.8	6.1	6.9	6.6	33.0	
0	0.4	5.8	6.5	7.1	6.9	6.8	34.1	
0	0.5	5.8	6.7	6.8	6.5	6.7	33.3	
0	1.0	6.0	5.5	5.7	5.8	5.7	28.3	

70°C water bath for 30 minutes
10 percent water added

* Significance ($P < 0.05$).

TABLE 2 The cookhouse yield data for pork rolls

Sample		% Shrink*
0.00% NaCl	0.0% TPP	29.0
0.75% NaCl	0.0% TPP	20.5
0.75% NaCl	0.3% TPP	16.0**
0.75% NaCl	0.5% TPP	15.0**

* Average % loss for 8 rolls per sample
Cooked to internal temperature of 71-75°C.

** Significance ($P < 0.05$)

TABLE 3 Effects of sodium chloride and sodium tripolyphosphate on the sensory characteristics and preference rating of nonirradiated pork roll

0 days storage

Sample		Sensory Characteristics				
% NaCl	% TPP	Color	Odor	Flavor	Texture	Preference
0.00	0.0	6.0[b]	5.9	5.7	5.2	5.9
0.75	0.0	6.0	5.7[b]	5.9	6.4[a]	6.1
0.75	0.3	5.7[b]	6.0	6.2	6.5[a]	6.2
0.75	0.5	5.7	5.8	6.2	5.7	6.0

12 panelists

30 days storage

0.00	0.0	7.1	6.7	5.6	6.1	6.1
0.75	0.0	6.9	7.0	6.9	6.9	6.9
0.75	0.3	6.9	7.0	6.7	6.7	6.5
0.75	0.5	6.5	6.7	7.1[a]	6.9	6.7

8 panelists

[a] Significantly different from the sample with no additives.

[b] Significant differences found in scores between 0 and 30 days stored samples.

Significance ($P < 0.05$)

TABLE 4 Effect of sodium chloride and sodium tripolyphosphate addition on the sensory characteristics and preference ratings of irradiated pork roll

0 days storage

Sample		Sensory Characteristics				
% NaCl	% TPP	Color	Odor	Flavor	Texture	Preference
0.00	0.0	6.2	6.2	5.2[a]	5.0	5.5
0.75	0.0	6.0	5.8	5.8	6.2	5.5
0.75	0.3	5.5	5.8	5.5	5.9	5.5
0.75	0.5	5.7	5.9	5.4	6.0	5.6

12 panelists

30 days storage

0.00	0.0	6.1	6.2	6.2	6.0	5.9
0.75	0.0	6.3	5.7	6.2	5.8	5.8
0.75	0.3	6.0	6.2	6.2	5.6	6.0
0.75	0.5	6.1	6.3	6.0	6.4	6.0

10 panelists

Irradiation: 5.1-6.1 Mrad at $-30^{\circ}C \pm 10^{\circ}C$

[a]Significant differences found between 0 and 30 days storage for flavor ratings.

Significance ($P < 0.05$)

TABLE 5 Effects of sodium chloride and sodium tripolyphosphate addition on irradiated and nonirradiated pork rolls

0 Days Storage

Samples			Sensory Characteristics				
% NaCl	% TPP	Dose	Color	Odor	Flavor	Texture	Preference
0.00	0.0	5.1 Mrad	5.7	5.6[b]	5.2	5.4	5.6
0.75	0.0	5.1 Mrad	5.9	5.2[b]	5.4	5.7	5.3
0.75	0.3	5.1 Mrad	4.7	4.8[b]	4.7	5.2	5.2
0.75	0.5	5.1 Mrad	5.8	5.7	5.5	5.6	5.7
0.75	0.3	0.0 Mrad	7.0[a]	6.7	7.1[a]	7.0[a]	7.4[a]

12 panelists

[a] Significantly different from other samples.

[b] Significantly different from the nonirradiated sample.

30 Days Storage

0.00	0.0	5.1 Mrad	5.9	4.8[a]	5.5	5.0[a]	5.2[a]
0.75	0.0	5.1 Mrad	5.7	5.4[a]	5.6	5.3[a]	5.7[a]
0.75	0.3	5.1 Mrad	6.3[c]	6.1[bc]	5.9[c]	6.1[c]	6.1[bc]
0.75	0.5	5.1 Mrad	6.2	6.5[b]	6.1	5.7	6.2[b]
0.75	0.3	0.0 Mrad	6.5	6.9	6.8	6.8	7.2

10 panelists

[a] Significantly different from the nonirradiated sample.

[b] Significantly different from the sample with no additives.

[c] Significant differences found between 0 and 30 days stored samples.

Significance ($P < 0.05$)

TABLE 6 Consumer evaluation of pork rolls with varying concentration of NaCl and TPP

Samples	Non-Irradiated	Irradiated 5.1 Mrad at -30°C ± 10°C	Irradiated with control
0.00% NaCl 0% TPP	5.3	4.6	4.3
0.75% NaCl 0% TPF	6.5[a]	6.0[a]	5.3[a]
0.75% NaCl 0.3% TPP	6.6[a]	6.5[a]	6.0[a]
0.75% NaCl 0.5% TPP	7.1[a]	6.7[b]	5.9[a]
0.75% NaCl 0.3% TPP (Frozen Control)	——	——	6.6[b]

32 panelists per test

[a] Significantly different from the sample with no additives.

[b] Significantly different from the no additive sample and NaCl only sample.

Significance (P <0.05)

TABLE 7 Effects of NaCl and TPP additions on the sensory characteristics of irradiated pork roll

Sample	Sensory Characteristics						
	Discol-oration	Off Odor	Irrad. Flavor	Off Flavor	Mushi-ness	Friabil-ity	Pref-erence
Control**	1.6	1.5	1.0[c]	1.5	1.1[c]	1.2[c]	6.5
0.0% NaCl* 0.0% TPP	2.1	2.0[a]	2.5	1.8	1.8	2.9	5.2[a]
0.5% NaCl* 0.0% TPP	2.6[a]	1.9	1.4[b]	1.4	2.4	2.6	5.5[a]
1.0% NaCl* 0.5% TPP	2.7[a]	1.9	1.5[b]	1.4	2.1	2.4	5.8
1.5% NaCl*	2.3	1.8	2.2	1.3	2.4	2.5	6.0[d]

23 panalists

* Irradiation: 5.1-6.1 at -30°C ± 10°C

**Nonirradiated control prepared with 0.75% NaCl and 0.3% TPP

[a] Significantly different from the control samples.

[b] Significantly different from the samples with 0: and 1.5% NaCl.

[c] Significantly different from the other samples.

[d] Significantly different from the sample with 0% NaCl.

Significance ($P < 0.05$)

TABLE 8 Consumer evaluation of nonirradiated pork rolls with various concentrations of NaCl and TPP

Sample	Storage Time-Mos.	Preference Scores
0.0% NaCl + 0.0% TPP	0	6.2
	1	5.7
	3	5.2
0.5% NaCl + 0.5% TPP	0	7.0
	1	7.2*
	3	6.5
0.75% NaCl + 0.5% TPP	0	6.5
	1	6.5
	3	7.1*
1.0% NaCl + 0.5% TPP	0	7.2*
	1	6.9
	3	7.1
1.5% NaCl + 0.5% TPP	0	6.7
	1	6.7*
	3	6.6

35 panelists

* Significantly preferred to the 0.0% NaCl, 0.0% TPP sample

Significance ($P < 0.05$)

TABLE 9 Effects of phosphate level on the sensory characteristics and preference of pork roll

Sample							
% NaCl	% TPP	Dose	Color	Odor	Flavor	Texture	Preference
			1 Month Storage				
0.75	0.3	5.1 Mrad	6.0	5.7[b]	5.2[b]	6.1	5.5
0.75	0	5.1 Mrad	6.0	5.4	4.7	5.4	5.2
0.75	0.3	0 Mrad	6.5	7.0[a]	7.0[a]	7.0[a]	6.8[a]
0.75	0	0 Mrad	6.9	6.7	6.6	7.1[a]	6.5[a]
			3 Month Storage				
0.75	0.3	5.1 Mrad	6.6	6.4[b]	6.1[b]	6.1	5.9[b]
0.75	0	5.1 Mrad	6.0	5.7	5.0	4.7	5.4
0.75	0.3	0 Mrad	7.5[a]	7.5[a]	7.4[a]	7.1[a]	7.1[a]
0.75	0	0 Mrad	6.6	6.9[a]	7.0[a]	6.7[a]	6.1

12 panalists

12 panalists 5.1 Mrad at -30°C ± 10°C

[a] Significantly different from the sample with 0.75% NaCl 0% TPP, irradiated.

[b] Significantly different from the nonirradiated sample with 0.75% NaCl, 0.3% TPP.

Significance ($P < 0.05$)

TABLE 10 Effects of additives on the total organic reducing volatiles of pork roll

Samples

Additives		Non-Irrad.		Irrad.* 0 storage		Irrad. 30 days storage	
		pH	ORV**	pH	ORV**	pH	ORV**
0% NaCl	0% TPP	6.2	1.05	6.4	1.24	6.1	1.86
0.75% NaCl	0% TPP	5.9	1.14	6.0	1.14	5.9	1.15
0.75% NaCl	0.3% TPP	6.1	1.13	6.3	1.25	6.2	1.22
0.75% NaCl	0.5% TPP	6.4	0.90	6.7	1.27	6.4	1.81

* 5.1-6.1 Mrad at -30°C ± 10°C

** Organic reducing volatiles, milliequivalent oxygen per 100 g meat.

TABLE 11 Shear press values for pork roll slices with various concentrations of NaCl and TPP

Sample		Shear Values*	
% NaCl	% TPP	Irradiated	Frozen Control
0	0	27.4	28.4
0.75	0	19.6[a]	29.4[c]
0.75	0.3	14.7[b]	20.6[b] [c]
0.75	0.3	13.7[b]	21.6[b] [c]

* Shear force in newtons required to penetrate 12.7 mm thick pork slice

[a] Significantly different from the sample with no additives

[b] Significantly different from the samples with no additives and 0.75% NaCl

[c] Significance found between irradiated and frozen control

Significance ($P < 0.05$)